

from the camera, for the reasons indicated by Fig. 3, which is an extreme case in which the camera, or eye, R is supposed to be very near to the side of an animal, so far that his cross section has to be represented by a circle.

The summit of the outline as seen from R is H, giving the idea that the spine of the animal is as high as L, whereas it is really at K. The ratio of LO to KO is of course the same as that of LO/OR to KO/OR, that is to HO/OR; in other words as the tangent of LRO to the sine of the same angle. The values to be dealt with in reality, are very different from those in the diagram. OR is 240 inches and KO may be taken as 15 inches. It results that LRO is only $3^{\circ} 35'$. Now the tangent and sine of such a small angle are so nearly alike that LO:KO :: 100'00:99'85, which corresponds to a difference of less than 1/8th inch in a horse of 15 hands high, and is quite negligible.

In some fat stock, however, the backs are flat like tables. Here some artifice would be necessary to obtain the true height, such as by fixing a stud of say 2 inches in height to a surcingle. The top of the stud would then be the point of measurement, and 2 inches would be subtracted from the result.

We now come to the effect of obliquity of the median plane of the horse to the long sides of the rectangle. The hoofs of a thoroughbred horse are some 4 inches wide, and 4 inches apart, so that the closest distance between either S or T, and the nearest side of the rectangle, is 6 inches; therefore the utmost cross distance between S and T is (20-12) or 8 inches, and the length of ST in a horse of 15 hands in height may be taken as 60 inches. Therefore the maximum obliquity within the strip is as 8 to 60, or $0^{\circ} 13'33$, which corresponds to an angle of $7^{\circ} 39'$.

The foreshortening of the length ST (= 60 inches) is such that its foreshortened value must be multiplied by the secant of $7^{\circ} 39'$

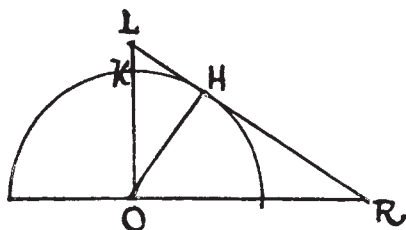


FIG. 3.

to obtain the unforeshortened value, that is by 1'009, which makes it nearly 1 per cent. longer. This is the greatest error to be feared under the conditions, and it is further much diminished by determining the actual obliquity. We can do this easily by measuring the distance lengthways between the points where ST produced cuts the opposite sides (not ends) of the rectangle. The further side of the rectangle affords the scale for reckoning distances from C along that line when produced; similarly the nearer side affords the scale for distances from C measured along and beyond itself. The cross distance between those points is known to be 20 inches, so the obliquity is easily found. The accompanying table may be found convenient. It applies with strictness only to objects viewed from a great distance, but is practically correct for much smaller ones.

Obliquity.	Multiplier to convert foreshortened values.	Corrections to be added to foreshortened measurements of			
		10 ins.	30 ins.	50 ins.	70 ins.
1 in 7	8 12	1'0103	in.	in.	in.
„ 10	5 43	0'100	0'20	0'50	0'70
„ 15	3 49	0'050	'15	'25	'35
„ 20	2 52	1'0022	'022	'07	'11
„ 25	2 18	1'0012	'012	'04	'06
„ 30	1 55	1'0008	'008	'02	'04
		1'0006	'006	'02	'03

The mean scale for the slightly oblique median plane is the perspective length of the rectangle at the point where a line drawn through the middle of ST cuts the perspective viewed ends of the strip. It is unnecessary to attempt greater

minuteness, as by determining the vanishing point (the position of which is given by prolonging two or more of the cross-lines upon the ground to their points of common intersection in the photograph), and then employing the further methods known to draughtsmen in perspective. Much could be written of which it is unnecessary to speak here, because it is a condition that the obliquity shall never be great. A strict attention to the elementary requirements laid down above, makes the problem of measurement extremely simple; otherwise it becomes complex and troublesome.

The next point to be considered is the method of measuring between points situated on the side of the horse, such as from the haunch bone to the shoulder. I shall speak of these in general terms only, because the most suitable points for measurement have yet to be determined. Whatever they be, it is a great assistance, before photographing the horse, to mark the points to be measured either by chalk, or more neatly by a disc of gummed paper, the size of a shilling, wetted and stuck on. Veterinary-Captain F. Smith has used both these plans. It is also an excellent plan to prick through these points in the photograph, and through a piece of paper laid below, and to measure between the prick holes. The general principle of dealing with these measurements is to find a mean correction suitable to each distance, when those distances have been calculated as if they were situated on the median plane. The lateral deviation from that plane of each one of these points, ranges within narrow limits, when the height of the horse is taken as unity. The mean deviation even of either protuberant haunch bone from the median plane between them, is much under 20 inches in a horse of 60 inches (15 hands in height). The mean range of this deviation in different horses of that height, judging from what occurs in anthropometric measurements, is probably very much under an inch, and its extreme range in ordinary cases would be under 2 inches. Extraordinary cases of massive or slender build would be betrayed by the photograph itself, and could be allowed for. It seems, then, that after the desirable points had been determined, between which measurements might be wanted, it would be a straightforward piece of work to make numerous measurements between them in different horses, and to draw up the suggested table of corrections for 2 or 3 different positions in the rectangle.

The head and neck can hardly be measured on the above principles, as it is very difficult to ensure that their median plane should be the same as that of the body. A strip of card chequered with inches, alternately white and black, and fastened to the head stall, affords a serviceable scale, and is by no means unsightly.

From measurements obligingly procured for me by Dr. MacFadyean, the Principal of the Royal Veterinary College at Holloway, the measurements being repeatedly made of the same horses by different pupils, I learnt two things. One was that horses of the same class vary among themselves as much as men. In short, they could be identified by a Bertillon method. The other was that the fallibility of a measurer was considerable. I think that measurements made on a half-plate photograph, under the conditions I have described, would on the whole be more trustworthy than direct measurements made with a tape or callipers, especially on fidgety horses.

FRANCIS GALTON.

THE MAGNETIC PROPERTIES AND ELECTRICAL RESISTANCE OF IRON AT HIGH TEMPERATURES.

THE magnetic properties of iron and, to a lesser extent, of the associated metals, nickel and cobalt, have always been a fascinating subject of study. Possessed by these three metals alone, these properties, so peculiar and so different from any of the other known properties of matter, have imparted to the study of these so-called magnetic metals a special charm and interest, apart from that excited by the vast industrial importance of at least one of them.

Among the very early inquiries into the nature of magnetism there were not neglected experiments on the effect produced by change of temperature. Three centuries ago, Gilbert recorded the observation that a piece of iron or steel, if heated more strongly than up to a full red heat, ceased to be attracted by a magnet, though it regained its previous magnetic qualities on cooling below that temperature.

Until comparatively recently, however, accurate magnetic measurements, even at ordinary temperatures, could alone be made on *permanent* magnets and the forces acting on their poles. The capability of acquiring *temporary* or induced magnetism when near a magnet, which is the characteristic property of soft iron, could not be subject to strict measurement until it was shown, firstly, how a given specimen of iron could be uniformly magnetised in a uniform magnetic field; and secondly, how both the magnetising force of that field, and the consequent magnetisation of the iron could be measured. We know of only one way of completely satisfying the first condition: namely, by covering a ring-formed specimen (whose outer diameter but slightly exceeds the inner) with a uniform layer of insulated wire carrying an electric current, thus forming a ring-magnet with no disturbing poles. And Faraday's researches on electro-magnetic induction have furnished us with a method, at once accurate and convenient, of determining the magnetisation of the apparently unmagnetised ring magnet, *i.e.* by the use of a "secondary winding" or outer layer of insulated wire, connected with a "ballistic" galvanometer. Knowing then the intensity of magnetisation called up by a given magnetising force, we can, from their ratio, express the facility with which the iron takes up magnetic induction, or, in other words, its magnetic *permeability*.

To apply this method to the measurement of permeability at high temperatures, both the magnetising and the secondary winding must be so insulated as to be uninjured by the heating; and further, the thermometer or pyrometer, which measures the temperature, must be placed inside the ring, so as to measure the actual temperature of the iron.

Among the earlier important researches on magnetic properties at high temperatures, that of Baur of Zürich, in 1879, should be mentioned. He experimented simply on an iron bar heated in a furnace, and thence rapidly transferred to the interior of a straight magnetising coil. Not, however, till 1889 was it shown by Dr. Hopkinson, in his classical researches, that the ring-magnet method could be successfully applied to the measurement of permeability at high temperatures. The windings of the ring-magnets were in this case of copper wire insulated with asbestos; the heating was carried out in a gas furnace; and the rise of temperature of the iron core was deduced from the increase of the electrical resistance of the secondary winding.

Of the more recent researches, the most remarkable is that of M. Curie, published in 1895, describing experiments on the magnetic behaviour of a great variety of substances, at temperatures ranging up to a white heat. The method he adopted—that of finding how strongly the specimens were attracted, when placed near a powerful magnet, was well adapted to determine permeability in intense magnetic fields, but it is much inferior to the ring-magnet method, where the permeability varies much with the magnetising force, as is the case whenever the magnetic field is not intense.

In the course of some experiments on the subject of this article, the results of which have been recently published, I have endeavoured to approximate, where possible, more closely than previous experimenters to the ideal method which would be the outcome of the principles laid down above. The ring-magnet, whose core was the iron specimen to be tested at high temperatures, was made very small, measuring about one inch across. The temperature of this core was determined by means of an electrical thermometer *embedded in it*, consisting of a wire of pure platinum whose electrical resistance at any temperature had been previously determined, and whose resistance, therefore, if subsequently measured, gave its temperature, and hence also that of the iron core in which it was laid. Asbestos paper insulation, as had been used by former experimenters, was found to be very imperfect at high temperatures, owing largely to carbon deposited from the materials used in its manufacture. This difficulty was, after some trouble, overcome; but wherever a high degree of insulation was wanted, as in the case of the thermometer wire and secondary winding, it was found necessary to employ *mica*, though, as may well be imagined, the use of such an untractable material for such a purpose is beset with considerable mechanical difficulties.

Now, to find the magnetic condition of a sample of iron at a given temperature with any completeness, it is not sufficient merely to measure its permeability in various magnetic fields; the behaviour of the iron when subjected to what is called a "cyclic" process of magnetisation must be studied—the

"hysteresis," or energy, absorbed in one double reversal of the magnetisation of each cubic centimetre of the iron, must be measured.

But the taking of so many observations requires time; and if, during this time, the temperature of the iron be not perfectly constant, all efforts at refinement in the magnetic measurements are thrown away. The heating of the ring must, then, be thoroughly under control. The method I adopted was an electrical one. The ring-magnet was furnished with an extra winding of asbestos-insulated platinum wire, so wound as to have no magnetising influence; and by passing through this wire a suitable electric current, heat could be generated in the ring at any desired rate. This method, however (the principle of which was adopted as long ago as 1888 by M. Ledebour) is not used to full advantage unless combined with an effort to thermally isolate the body to be heated. Each ring-magnet was therefore thickly wrapped with asbestos, and supported in the centre of a closed and partially exhausted glass vessel (oxidation of the iron core was also in this way avoided).

This method of heating proved most satisfactory. The loss of heat by radiation and conduction being slight, the ring-magnet could not rapidly alter its temperature; and there is probably no way in which we can supply heat-energy to a body, which can compete with the electrical resistance method, either as regards constancy or control. For obtaining temperatures up to 1300° or 1400° C.—a white heat—this method, combined as far as possible with "thermal isolation," and an electrical method of measuring the temperature, should in the future prove of the greatest value in all cases where the physical properties of bodies at high temperatures require careful investigation.

The original intention of my experiments was to ascertain exactly in what way the specific electrical resistance of iron changes at and about the "critical temperature" at which the magnetic properties of iron so nearly disappear, so as to throw light if possible on the molecular state which we characterise by the term "magnetic." With this object the iron core of the ring-magnet was formed of a long insulated iron strip, among the turns of which the platinum thermometer wire was buried; and with this piece of apparatus simultaneous measurements of the magnetic qualities and electrical resistance of a sample of iron could be made with accuracy alike at low and high temperatures.

Let us now consider the magnetic changes which occur in soft iron when heated. At ordinary temperatures iron shows a kind of unwillingness, so to speak, to become *slightly* magnetised—its permeability under small forces is not great. Beyond a certain limit, however, it exhibits the greatest readiness to become further magnetised, and continues to have a high permeability until magnetised very strongly. But from this point it begins to show signs of magnetic *saturation*, and ultimately refuses to be further magnetised without the application of very great force.

Now, as the temperature of the iron is gradually raised, it is found that practical magnetic saturation takes place sooner and sooner. Iron refuses to become so strongly magnetised at higher temperatures. Thus the permeability in strong magnetic fields falls off as the temperature rises—very slowly at first, then more rapidly, till, near the "critical temperature," the permeability rapidly drops to quite a low value.

On the other hand, in weak magnetic fields, the behaviour of iron up to within a few degrees of the "critical temperature" is precisely opposite. The permeability *rises* with the temperature—at first slowly, then above 500° C. with ever increasing rapidity, until at last that lack of susceptibility to small forces disappears, and iron shows itself just as amenable to magnetic influence in small magnetic fields, as in the larger ones, where the maximum permeability occurs.

At this temperature—say 15° below the critical temperature (about 750° C.—a red heat), iron possesses all those qualities at once which are sought after by the transformer maker:—Practical absence both of hysteresis and of eddy currents (the latter owing to the greatly increased electrical resistance), and a permeability nearly four times as great as that attainable in commercial transformer iron. So magnetic, indeed, is the iron, that even the earth's magnetic field, in the direction of its greatest intensity, is enough to induce strong magnetisation ($B = 5000$), in fact almost saturate the iron (for which at this temperature a relatively low induction suffices). The behaviour of a compass needle near a slowly cooling ingot of cast steel, should be rather interesting,

for just below the critical temperature the vertical ingot must behave as a very powerful magnet indeed.

For all the lesser magnetic fields, there is a temperature of maximum permeability which is nearer to the critical temperature the smaller the magnetic field. But at that temperature the magnetic qualities in almost all fields practically vanish. Hence, when the magnetising force is very small, the change from enormously magnetic to almost non-magnetic takes place with extreme suddenness.

Above the critical temperature, iron is but feebly magnetic; yet it is still much more readily affected by a magnet than most other feebly magnetic bodies. Not till a white heat is reached, do the magnetic qualities of iron become imperceptible.

It is not easy in an article like the present to deal with the changes which occur in the electrical resistance of iron, but the following remarks may be of interest:—

The experiments of Dewar and Fleming have shown that at a temperature of -200°C . the specific electrical resistance of iron is extremely low. Throughout the range of temperature included between that extreme of cold and the critical temperature, about $+780^{\circ}\text{C}$., the resistance rises at a steadily increasing rate, so that at the latter temperature it is over 150 times as great as the former: far in excess of that of any known alloy at ordinary temperatures (crystalline metals and their alloys excepted), and about equalling liquid mercury for high specific resistance. On still further raising the temperature of the iron, it is found that the rate of rise of resistance, instead of further increasing, very rapidly falls off till, at a white heat, the resistance of iron increases only slowly with the temperature.

It has long been known that this increasing rate of rise of resistance with temperature is a characteristic possessed by the magnetic metals alone. Here now we see that no sooner does the iron cease to be strongly magnetic than this quality disappears, and becomes exchanged for an opposite one, namely, a decreasing rate of rise of resistance with temperature. In some hitherto unpublished experiments on Hadfield's manganese steel (a non-magnetic steel which can be rendered magnetic by annealing), I have observed a precisely similar change of the resistance-temperature function to take place during the annealing of this steel, thus furnishing a second case of this obscure resistance-change accompanying the change from magnetic to non-magnetic, in one and the same sample.

The connection between magnetic and electrical properties is evidently not a very simple one, but in the face of these facts it is hard to deny that there is one; and it is only by trying to find out how the various physical properties depend upon magnetism that we may hope to arrive at a comprehensive explanation of that obscure but most interesting condition of matter.

DAVID K. MORRIS.

EARLY MAN IN SCOTLAND.¹

IN Scotland, as in other countries, man existed before the time of written history. The conditions under which his remains are found, and the works which he has left behind him, provide the data for determining their age, not absolutely or capable of being expressed in numbers of years, but relatively to each other.

Marked differences existed in the physical conditions of Scotland, and indeed in the northern parts of England also, as compared with the southern districts of England and the adjoining parts of France and Belgium at the first appearance of primeval man in those countries. It is the more necessary, therefore, that the conditions then prevailing in Scotland should not be overlooked.

No evidence sufficient to satisfy geologists has been advanced to prove that man existed in Britain during the period called Tertiary. So far, indeed, as Scotland is concerned, even if it were admitted that in other parts of the globe man had been on the earth during Tertiary times, there is little likelihood that his remains could have been preserved; for in that country the Tertiary is represented chiefly by volcanic rocks, and a few patches of sand and gravel with rolled sea shells belonging to the closing stages of that period.

From the careful study which geologists have given to the surface of Scotland, it is evident that at the commencement of the period termed Quaternary or Pleistocene, immediately suc-

ceeding the Tertiary, the whole of the country was covered with ice which formed a great sheet 3000 or 4000 feet thick in the low grounds, of which the lower boulder clay, or Till, as it is termed, was the ground-moraine.

As an upper boulder clay also occurs, which is often separated from the lower boulder clay by stratified deposits, some of which contained marine, and others fresh water and terrestrial organic remains, it is obvious that the Ice Age was not one uninterrupted period of continuous cold.¹ The lower and upper tills are the ground-moraines of independent ice sheets, each indicating a distinct epoch, separated by an interglacial period. The earlier epoch was that of maximum glaciation, and the ice sheet extended over the north and middle of England, as far south as the Thames Valley and the foot of the Cotswold Hills; but the high moors in Derbyshire and Yorkshire and the tops of the highest mountains in Wales and Scotland rose above its surface. The great Mer de Glace stretched westward over Ireland into the Atlantic, whilst on the east it was continuous across the North Sea with a similar ice sheet which covered Scandinavia and the region of the Baltic, and extended south to the foot of the hills of central Europe, and overspread much of the great central plain. In the extreme south of England, therefore, the conditions differed from those that obtained in the country further north. Although not actually covered with a sheet of ice, yet the more southern counties had been of necessity under the influence of cold, and must have been subjected to the effects produced by rain and snow, by freezing and thawing.

During the succeeding interglacial epoch the climate eventually became temperate and genial, and vegetable and animal life abounded. It is to this stage that most of the Pleistocene river alluvia and cave deposits of England and the adjacent parts of the continent are assigned. The British Islands appear at that time to have been joined to the continent, and the same mammalian fauna then occupied Britain, France and Belgium, which implied similar climatic conditions. As examples of these, it may be sufficient to name the larger mammals, as the cave and grizzly bear, the hyæna, lion, Irish deer, reindeer, hippopotamus, woolly rhinoceros, straight-tusked elephant and mammoth, all of which are now either locally or wholly extinct.

Abundant evidence exists that man was contemporaneous with these mammals in western Europe, as is shown by the presence of his bones alongside of theirs, and of numerous works of his hands, more especially the implements and tools which he had manufactured and employed. To a large extent these consisted of flint, rudely chipped and fashioned. To these implements, and to the men who made them, the well-known term "Palæolithic" is applied. But along with these, other implements have been discovered, made from the bones, horns and teeth of the larger mammals, on some of which animal forms and incidents of the chase have been sculptured both with taste and skill. Up to now, however, no trace of pottery which can without question be referred to Palæolithic men has been found, and no habitations, except the caves and rock shelters which nature provided for them.

One may now consider how far northwards in Britain Palæolithic man and the large mammals, with which he was contemporaneous, have been traced. The exploration of caverns, made by Prof. Boyd Dawkins and other geologists associated with him, has proved that bones of certain of the mammals of this epoch were present in caves in Derbyshire, Yorkshire and North Wales, and that human remains and implements of Palæolithic type have been found along with them in the Robin Hood cave in the Cresswell Crags, and in caverns in North and South Wales.

When Scotland is considered, evidence of the existence of the mammals of this epoch is not so abundant, yet the interglacial beds of that country have yielded remains of mammoth, reindeer, Irish elk, urus, and horse. But notwithstanding the keen scrutiny to which the superficial deposits in Scotland have been subjected by the members of the Geological Survey and others, no traces either of the bones of Palæolithic man or of the work of his hands have been discovered in North Britain. This, indeed, is not much a matter of surprise, for it must be remembered that, subsequent to the genial interglacial epoch, another ice sheet, that of the upper boulder clay, made its appearance, grinding over the surface of the land, wearing away alluvia, and largely obliterating the relics of interglacial times. Hence inter-

¹ For the evidence on which these statements are based, consult the "Great Ice Age," by Prof. James Geikie, edition 1894, also his "Classification of European Glacial Deposits," in *Journal of Geology*, vol. iii., A May 1895.

¹ A discourse delivered at the Royal Institution, London, by Sir William Turner, F.R.S.